

Uncertainty of Passive Imager Cloud Optical Property Retrievals to Instrument Radiometry and Model Assumptions: Examples from MODIS

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Outline

1. MODIS Solar Reflectance Optical Property Retrievals and Uncertainties
 - challenge: choosing a subset of error sources that can be quantified and are operationally viable
2. Pixel-Level Uncertainties: MODIS Level-2 Example
3. Uncertainties in Aggregated Means: MODIS Level-3 Example

MODIS Collection 6 Cloud Retrieval (MOD06)



MODIS

Error Sources Explicitly Included in Collection 6 Uncertainty Calculations

- *instrument calibration (pixel-level, L1B file)*

- *atmospheric corrections: q (fwd. model LUT), O_3*

cloud retrievals (1 km): COT,
CER_1.6, CER_2.1, CER_3.7, CER_1.6/2.1
WP_1.6, WP_2.1, WP_3.7, WP_1.6/2.1

- *cloud model: droplet size distribution v_{eff}*

surface spectral reflectance/emission

Plane-Parallel Fwd. Model

- *Surface reflectance –*

Ocean: Cox-Munk wind speed/direction

Land: MODIS-derived gap-filled product

Snow/ice: MODIS-derived gap-filled database

- *3.7 μm retrievals: T_{sfc} , low cloud T_c retrievals, F_0*

cloud masking, cloud-top pressure provided
through separate algorithm team
(S. Ackerman et al.)

MODIS Collection 6 Cloud Retrieval (MOD06)



Error Sources NOT Explicitly Included in Collection 6 Uncertainty Calculations

MODIS

- long-term radiometric bias/drift
- above-cloud aerosol [added later, not in original talk]

cloud retrievals (1 km): COT,
CER_1.6, CER_2.1, CER_3.7, CER_1.6/2.1
WP_1.6, WP_2.1, WP_3.7, WP_1.6/2.1

surface spectral reflectance/emission

Plane-Parallel Fwd. Model

cloud masking, cloud-top pressure provided
through separate algorithm team
(S. Ackerman et al.)

- cloud model: vertical and horizontal heterogeneity (3-D radiative effects)



More egregious cases accounted for by
flagging obvious partly cloudy pixels

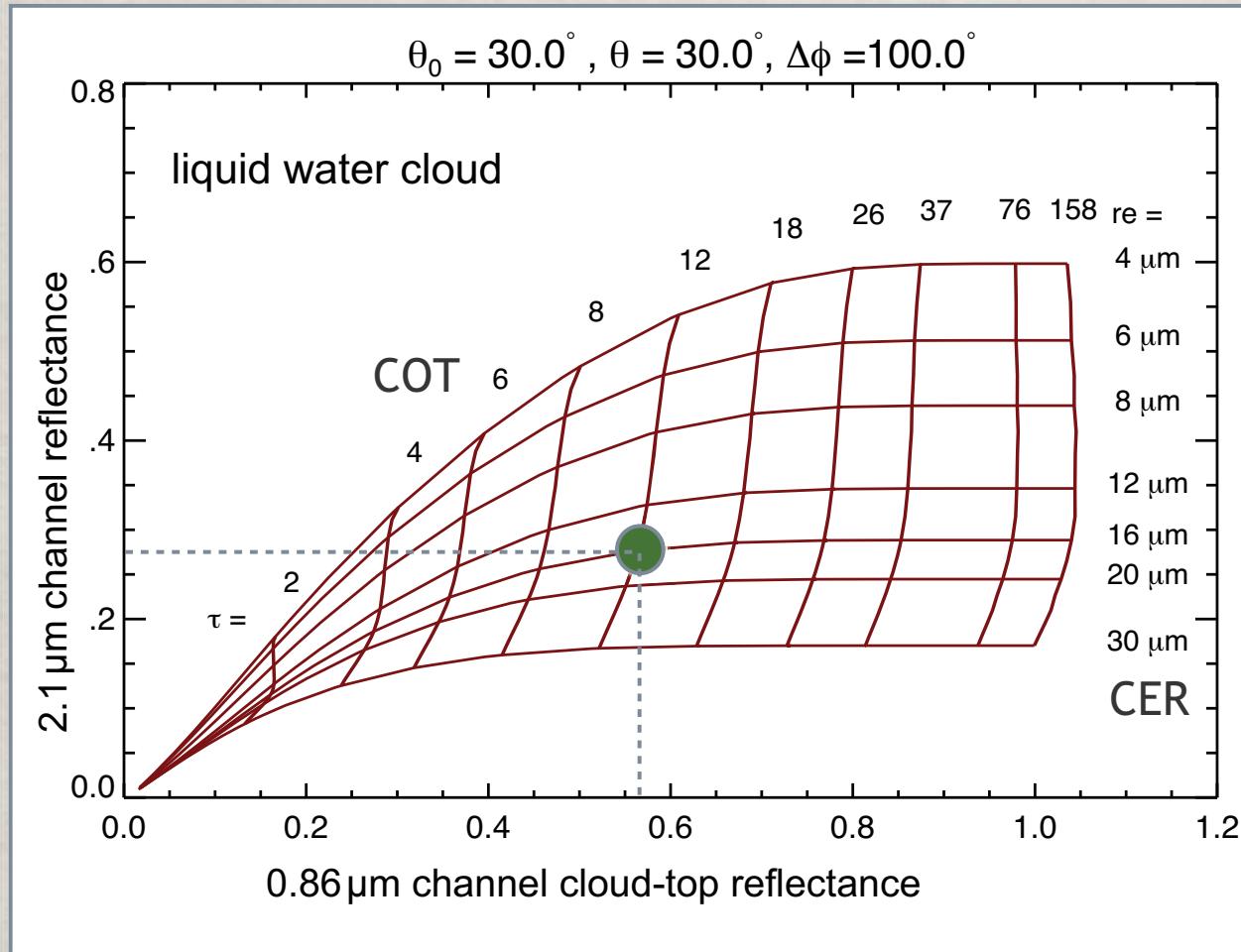
Other Error Sources Not Accounted for: Discrete Choices

- What is a cloud? What constitutes a cloudy FOV appropriate for a retrieval? [A44-03, Ackerman *et al.*]
- How to account for thermodynamic phase retrieval uncertainty?
- Choice of forward radiative cloud model (e.g., ice radiative models [A44B-07, van Diedenhoven *et al.*])?
- How to use Quality Assessment assignments (common in EOS and other products) or related information.
 - multiphase/multilayer scenes (MODIS has a multilayer flag)?
 - accounting for discrepancies from different spectral channel pairs? [A44B-08, Zhang *et al.*]

Subjectivity always comes into play. Sometime's it's explicit (developer says "I am making a subjective choice"), sometimes it's implicit.

Example MODIS Cloud Optical Thickness (COT) & Effective Radius (CER) Retrieval Solution Space

0.86 & 2.1 μm channel retrieval combination

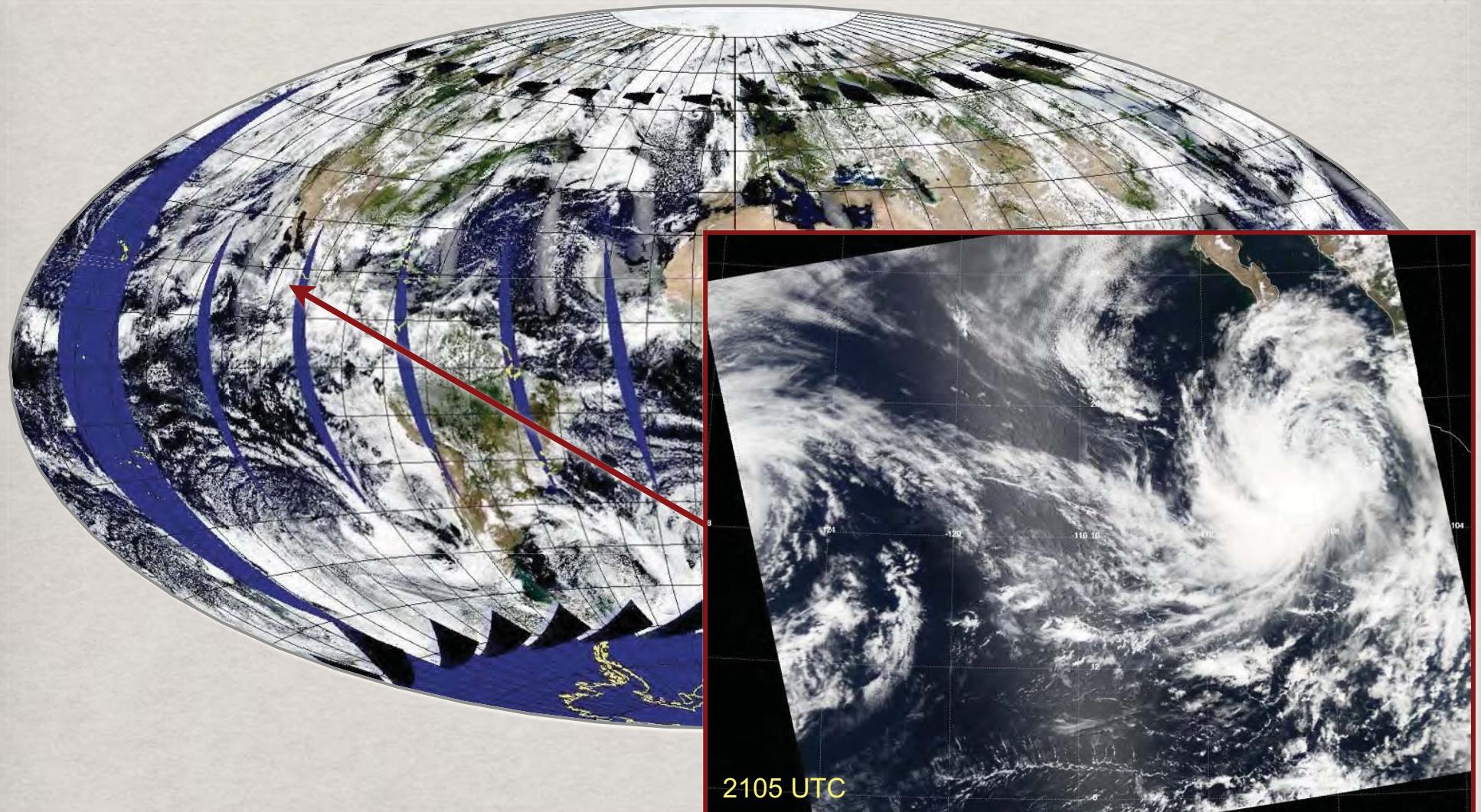


retrieval error covariance

$$\begin{aligned} & \left(\mathbf{K}^T S_y^{-1} \mathbf{K} \right)^{-1} \text{refl. meas. unc.} \\ & + \left(\mathbf{K}^{-1} \mathbf{K}_b \right) S_b \left(\mathbf{K}^{-1} \mathbf{K}_b \right)^T \\ & \text{maps model uncertainty} \\ & \text{into cloud-top reflect.} \\ & \text{uncertainty} \end{aligned}$$

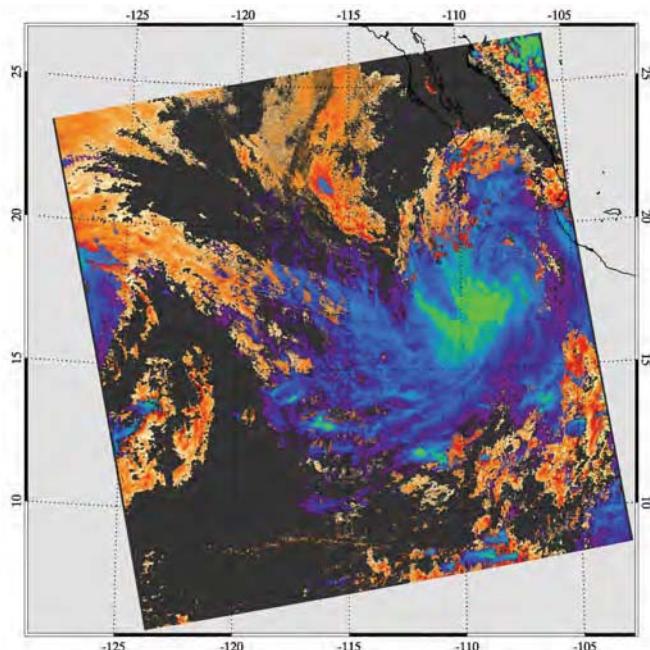
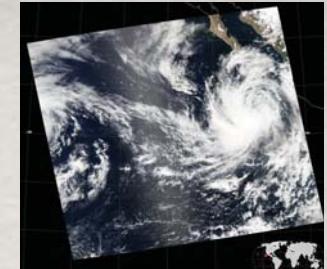
Pixel-Level Uncertainty Example

2 July 2008, MODIS Aqua

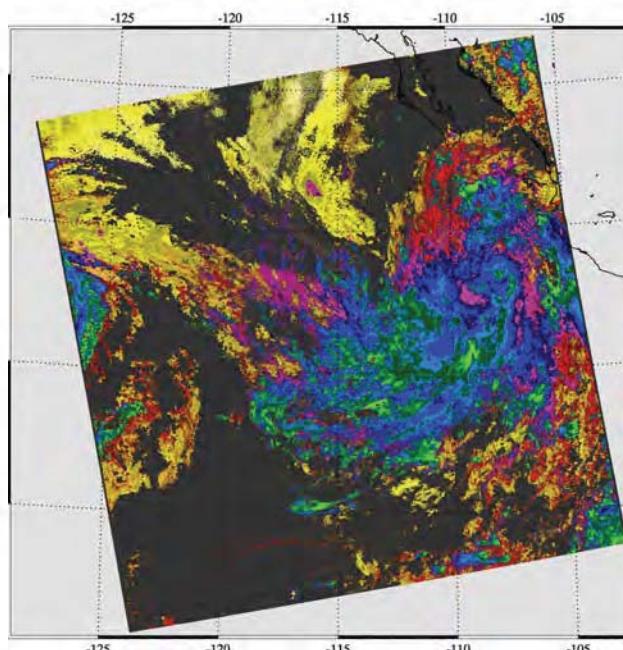
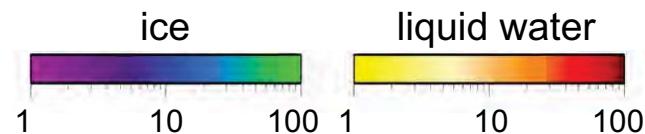


Pixel-Level Retrievals

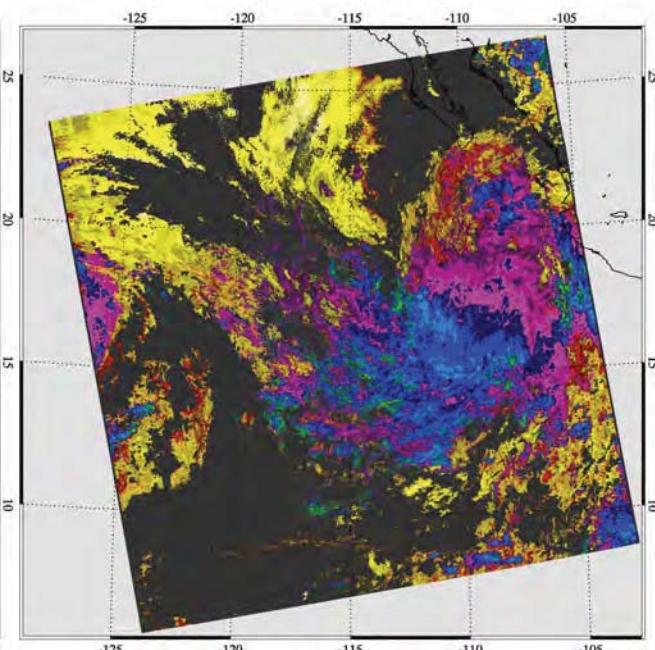
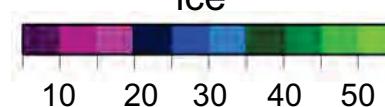
2 July 2008, MODIS Aqua C6, 2105 UTC
(best quality pixels only, CSR=0)



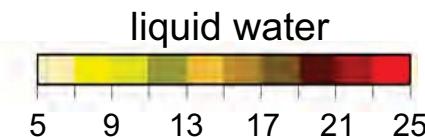
COT



CER_2.1 (μm)

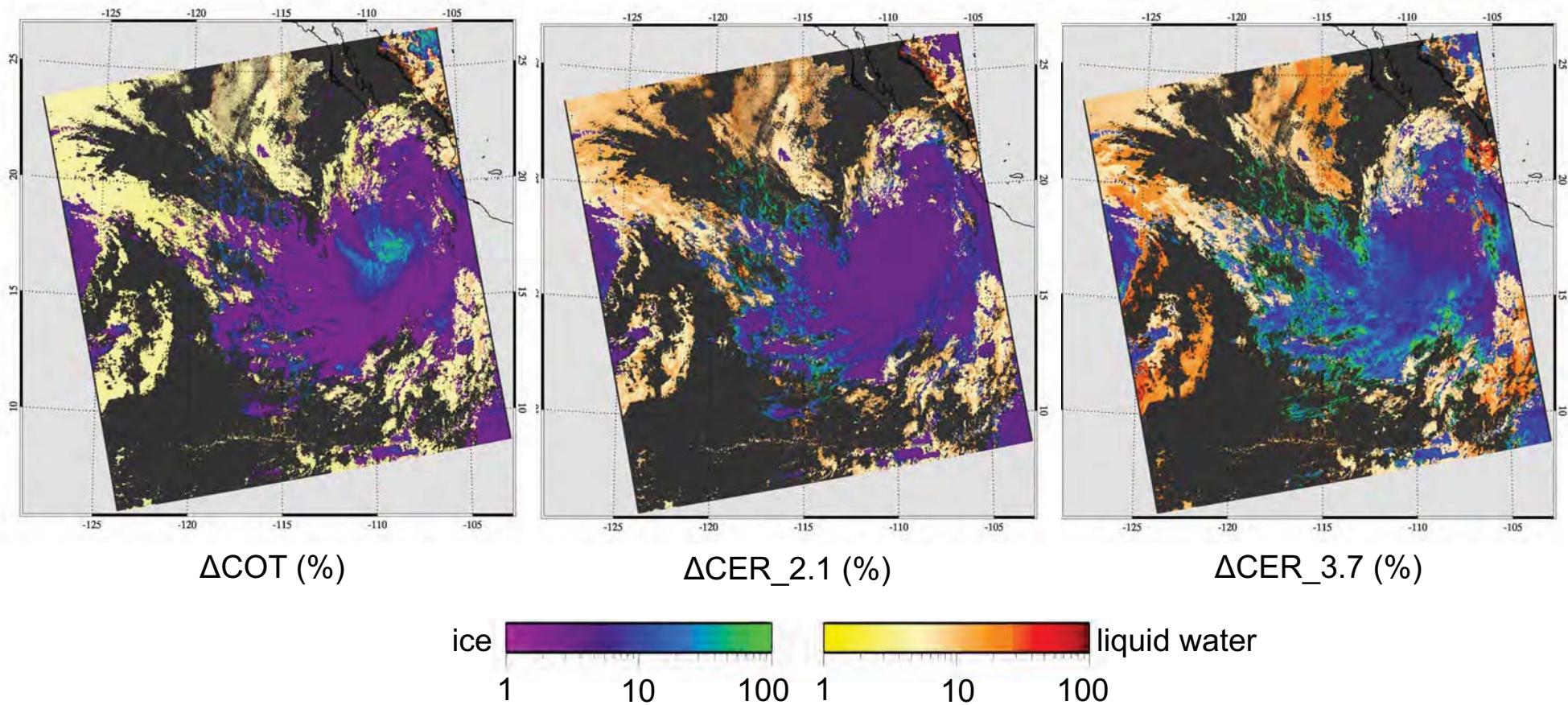
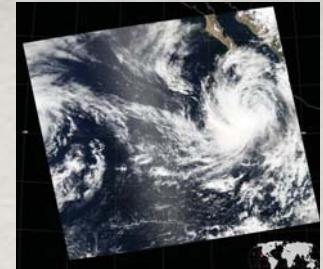


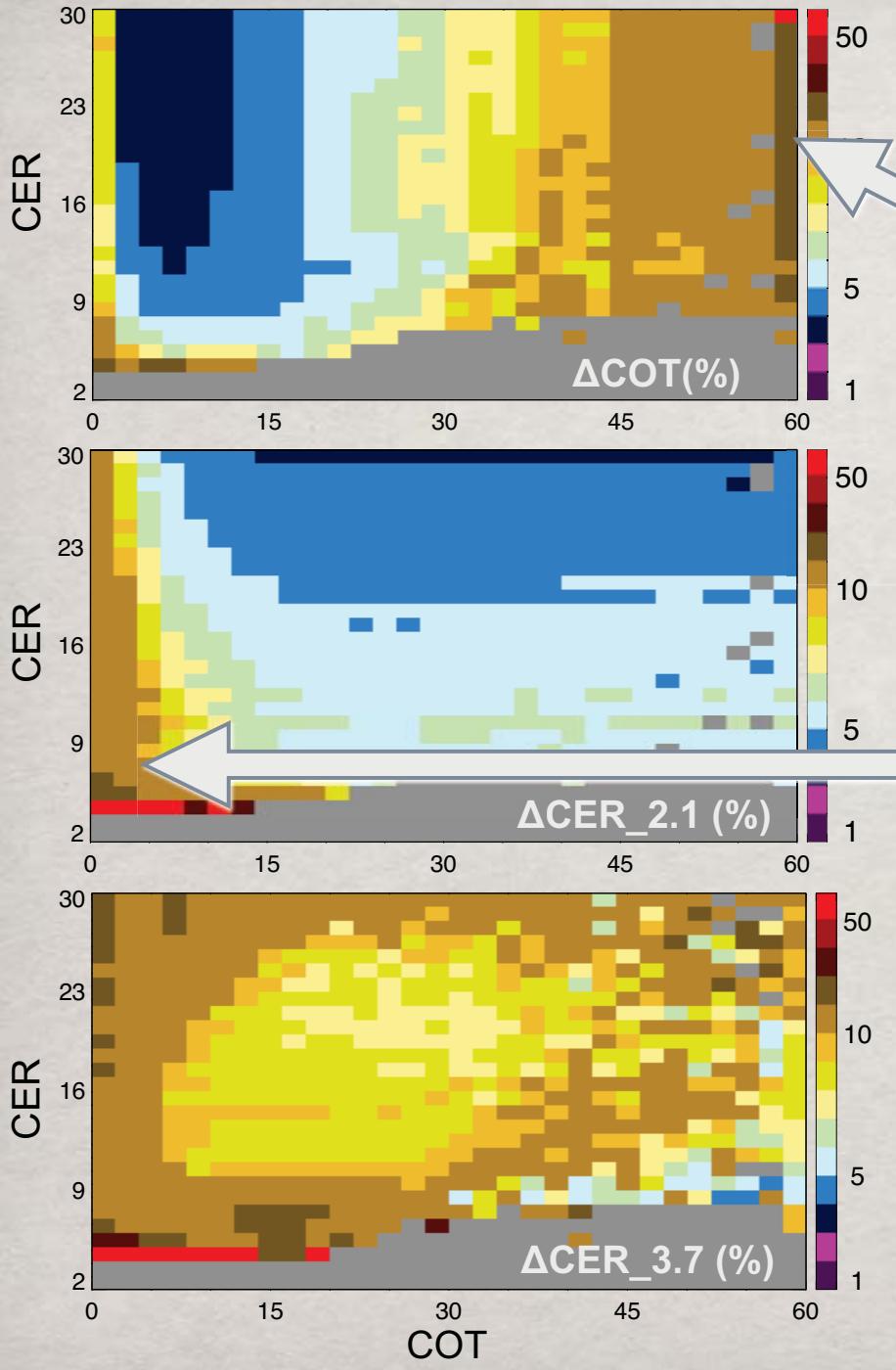
CER_3.7 (μm)



Pixel-Level Retrieval Uncertainties

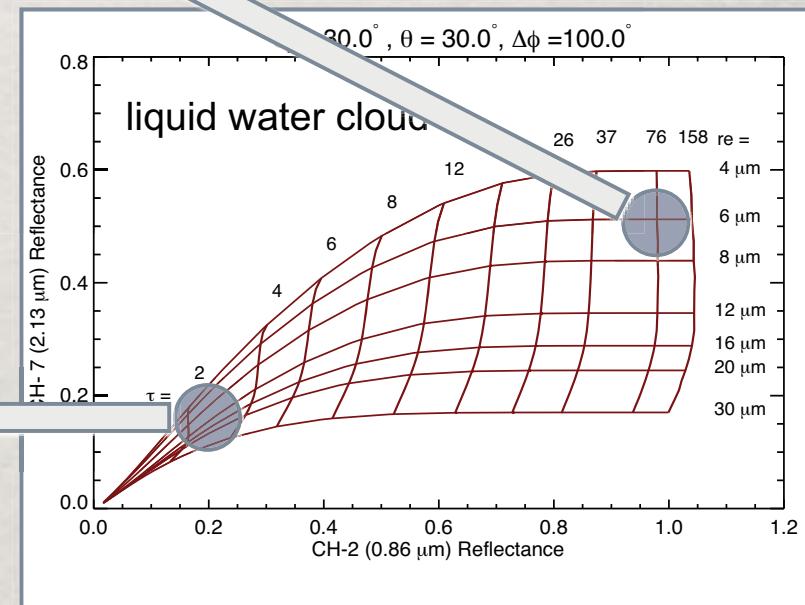
2 July 2008, MODIS Aqua C6, 2105 UTC
(best quality pixels only, CSR=0)





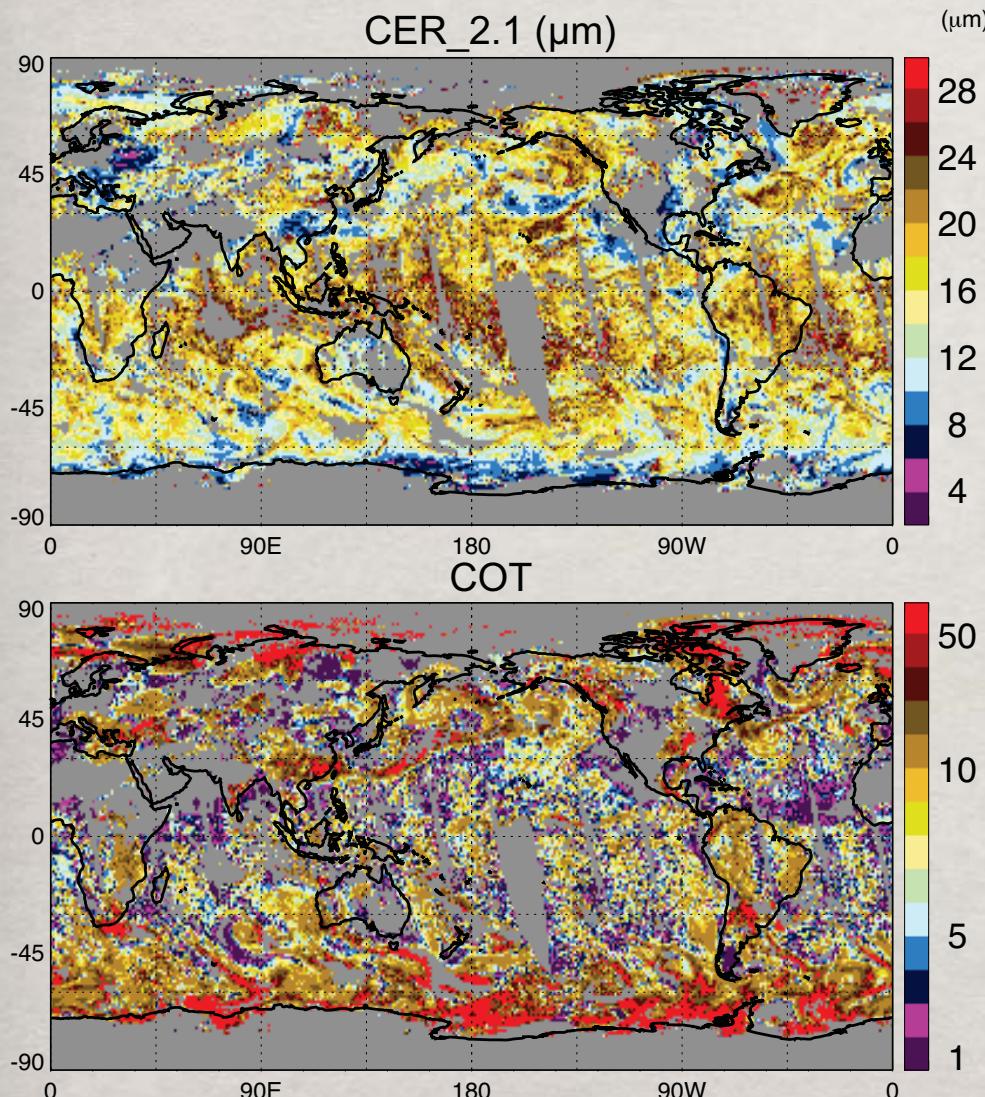
Mean Uncertainty vs. COT, CER Liquid Water Pixels

2 July 2008, MODIS Aqua



Uncertainties in Aggregated Means: Correlations?

Daily Means for Liquid Water Clouds

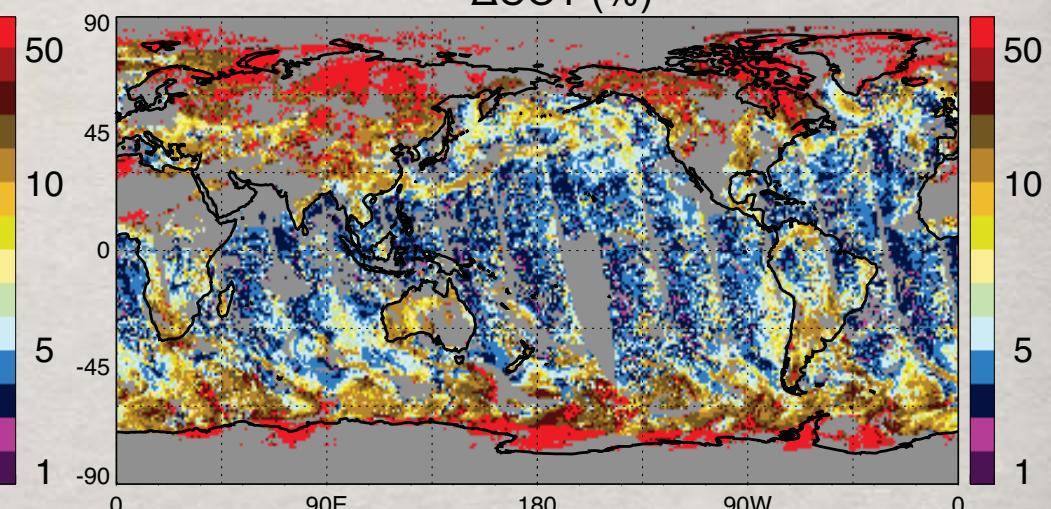
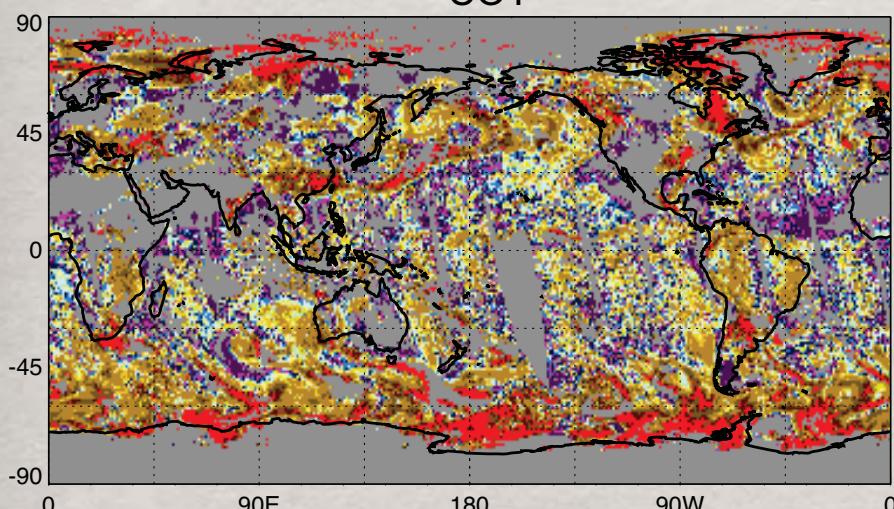
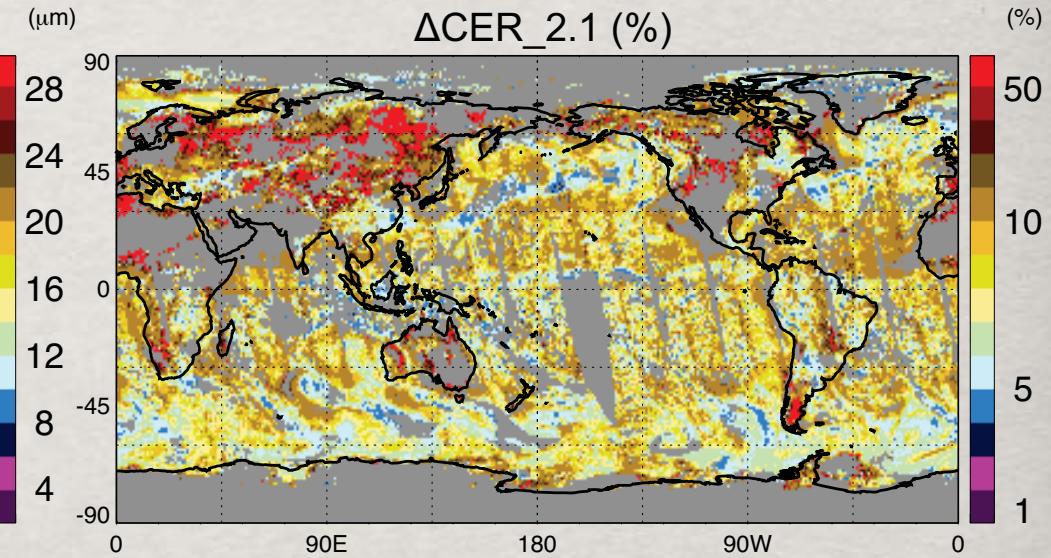
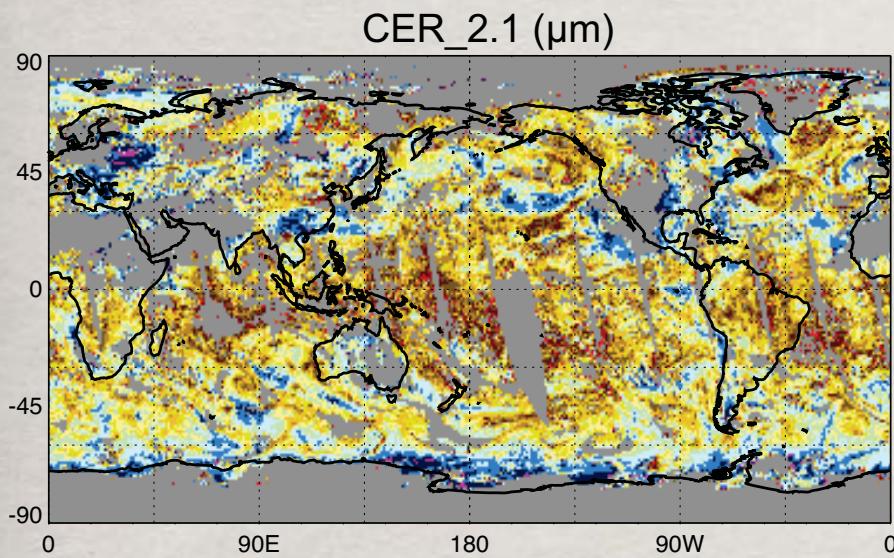


Platnick et al., AGU 2013

(MODIS Aqua C6, best quality pixels only, CSR=0)

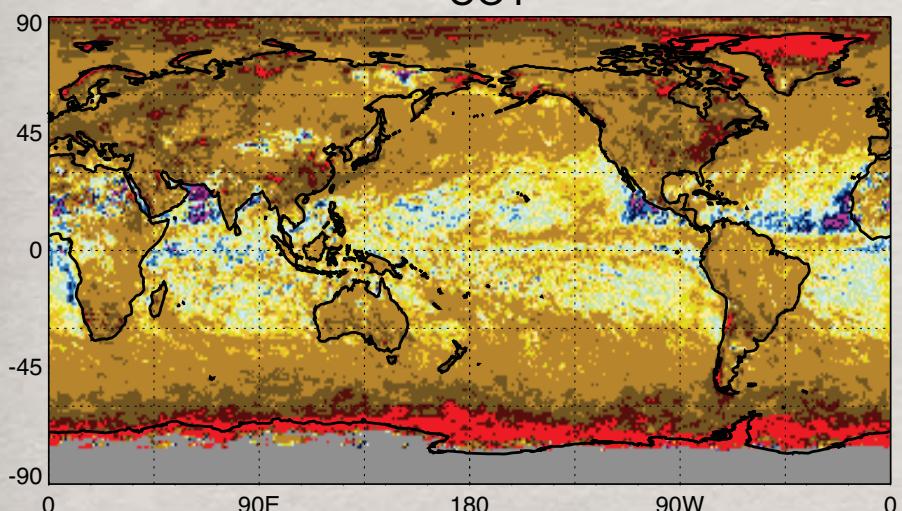
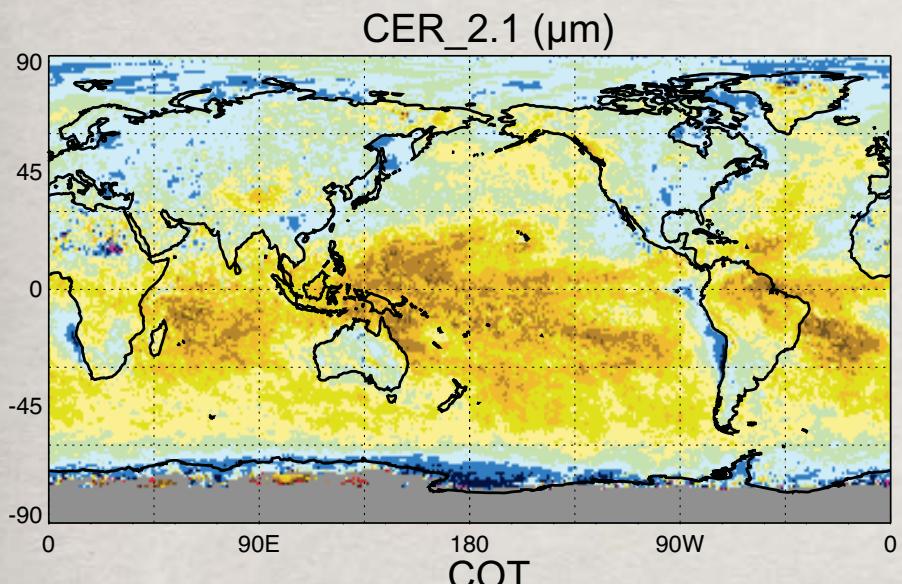
Uncertainties in Aggregated Means: Correlations?

Daily Means for Liquid Water Clouds

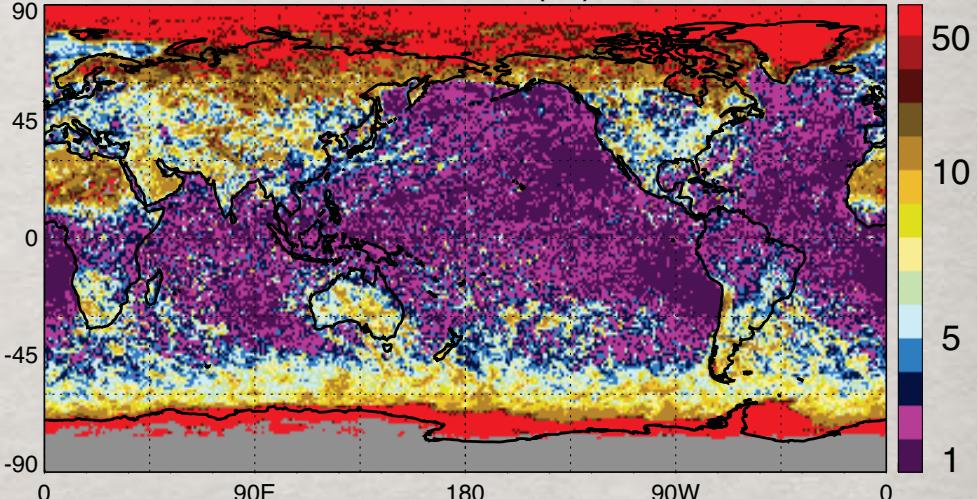
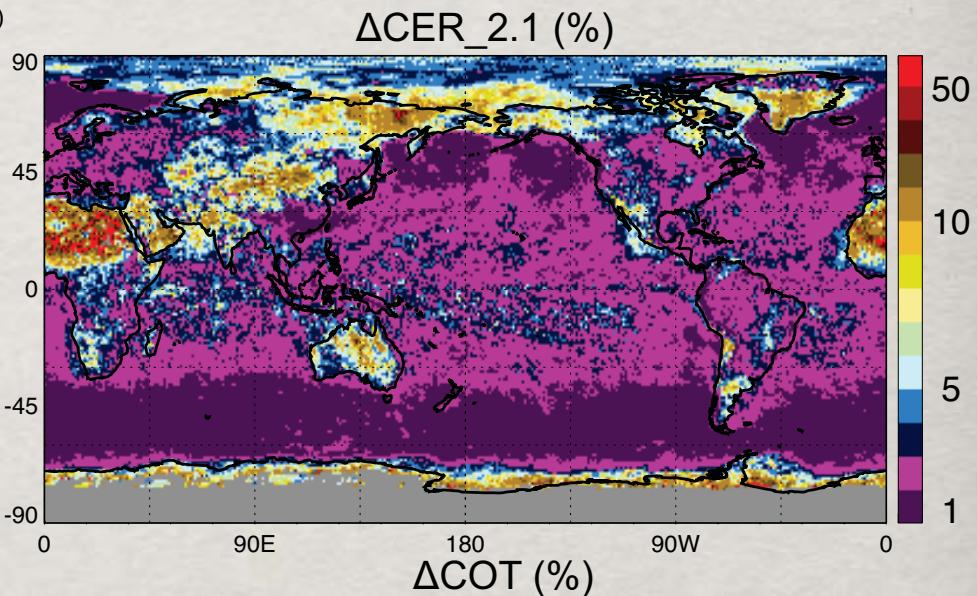


Uncertainties in Aggregated Means: Correlations?

Monthly Means for Liquid Water Clouds

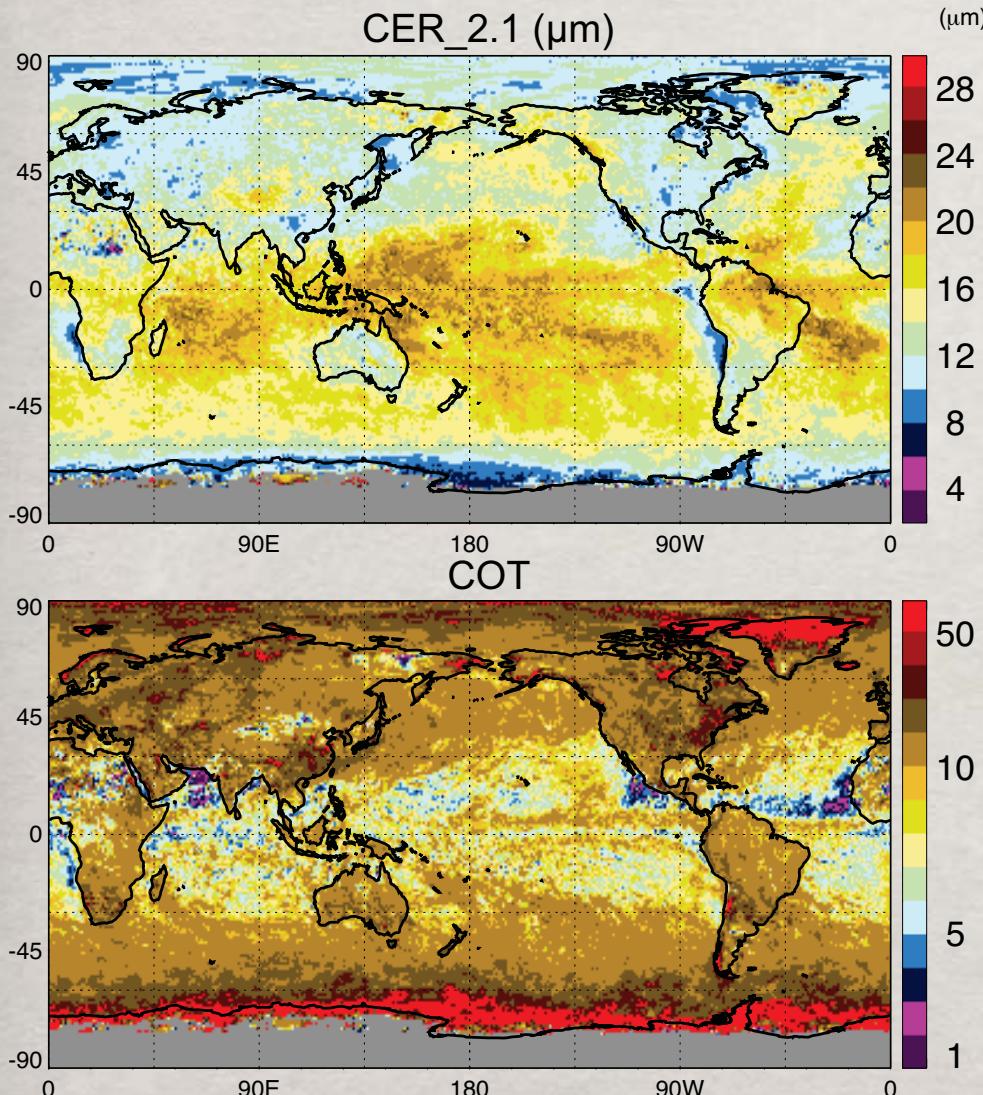


Monthly Uncertainty (April 2005)
w/day-to-day error correlation = 0



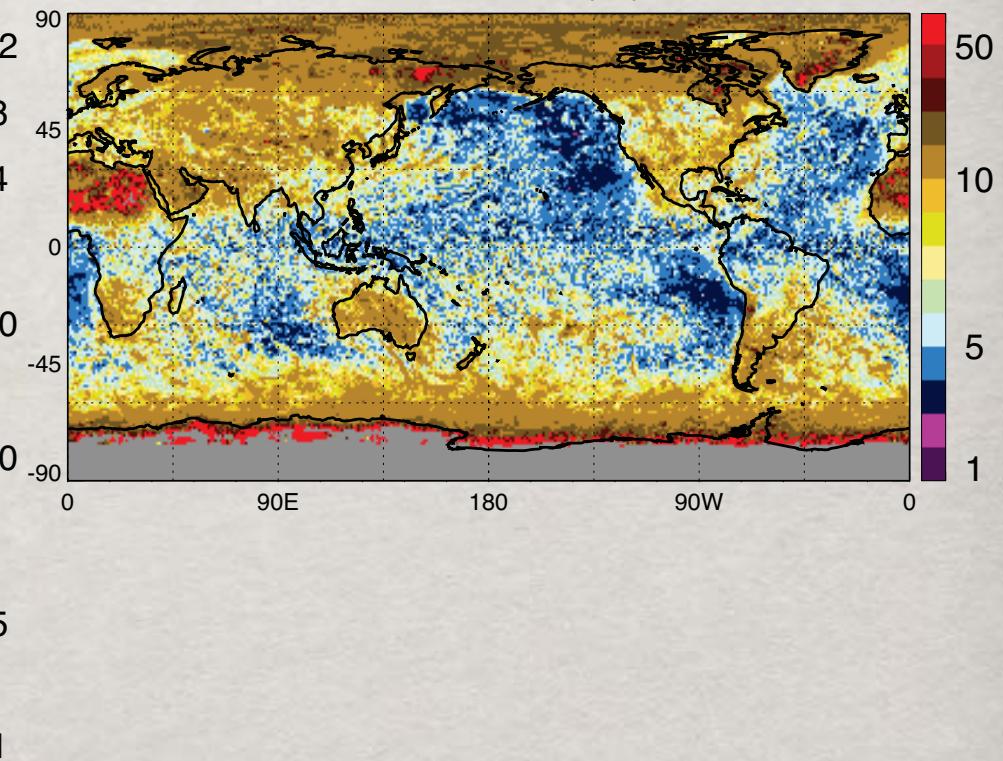
Uncertainties in Aggregated Means: Correlations?

Monthly Means for Liquid Water Clouds



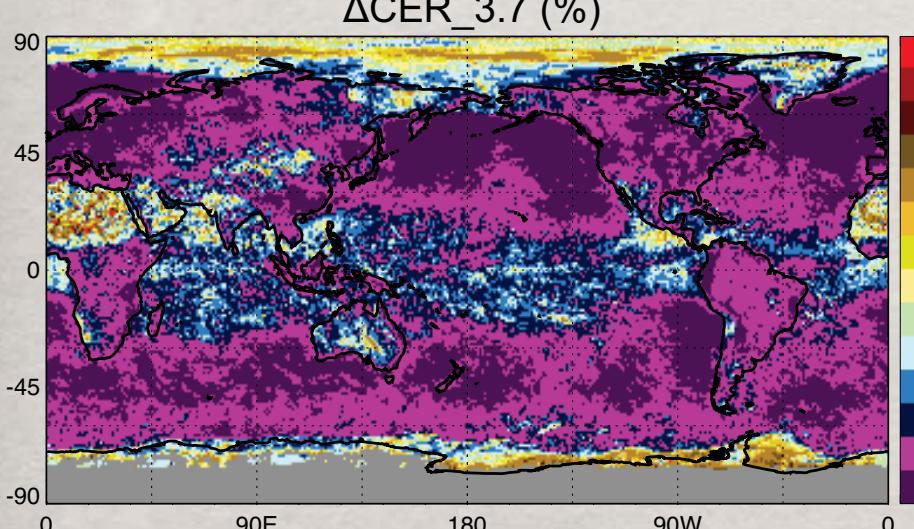
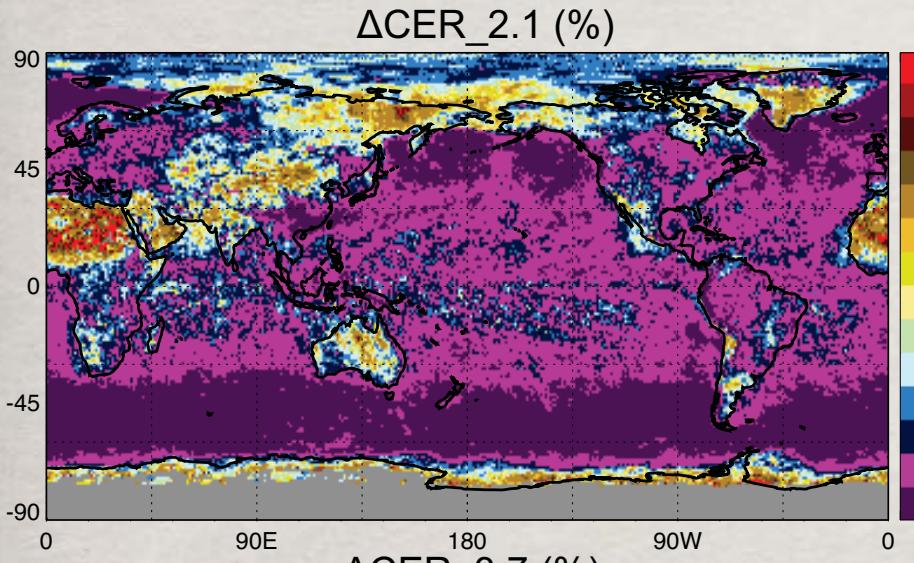
Monthly Uncertainty (April 2005)
w/day-to-day error correlation = 0

$\Delta\text{LWP}_2.1$ (%)

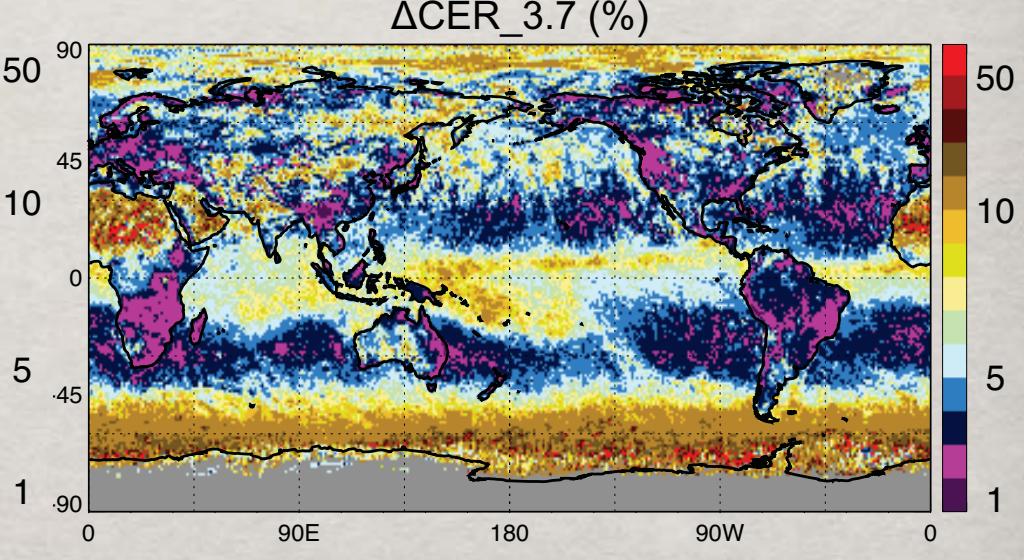
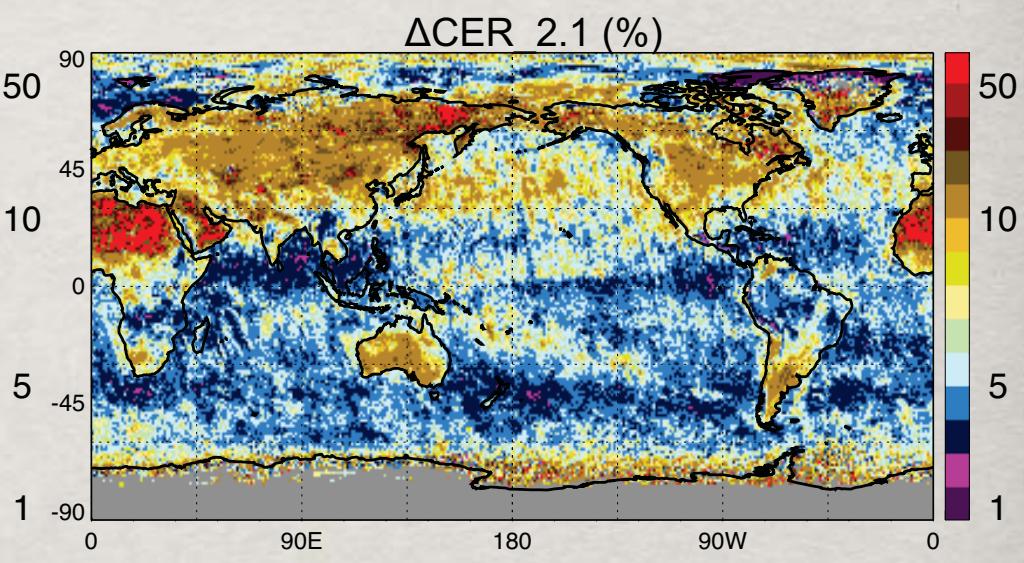


Uncertainties in Monthly Aggregated Means - Sensitivity

Monthly Unc. Liquid Water Clouds
Best Quality Pixel Aggregation



Monthly Unc. Liquid Water Clouds
“Partly Cloudy” Pixel Aggregation



Summary

- MODIS Collection 6 provides pixel-level COT, CER, and WP retrieval uncertainty estimates for the various spectral channel combinations
 - error sources: L1B spectral radiometric uncertainty assignments, atmospheric corrections (q , O_3), surface albedo/temperature, effect of temperature errors on $3.7\text{ }\mu\text{m}$ CER retrievals, limited cloud model parameters (effective variance, Cox-Munk wind vector)
- Issues:
 - How to quantify the impact of Algorithm Discrete decisions (cloud detection, phase) and Quality Assurance choices (pixel screening)?
 - Uncertainties in gridded statistics requires understanding pixel-to-pixel space/time correlations among the error sources!
- Cloud retrieval uncertainties cannot include all error sources (known and unknown unknowns) but should still be useful as a baseline estimate
- Data presented here is from the final Collection 6 algorithm. Aqua L2 reprocessing just started. Terra reprocessing will follow completion of Aqua.